

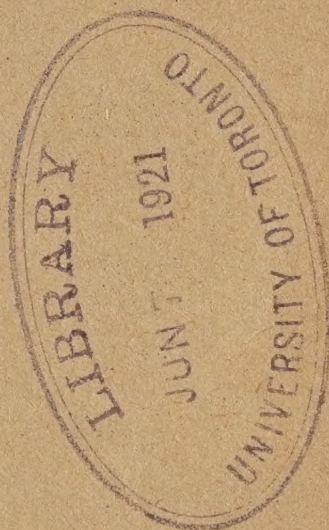
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CANADA, *Air Board*

THE AIR BOARD

REPORT ON
EXPERIMENTAL AERIAL SURVEY
AT OTTAWA
1920

BULLETIN No. 2



MARCH, 1921

OTTAWA
THOMAS MULVEY
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1921

CANADA

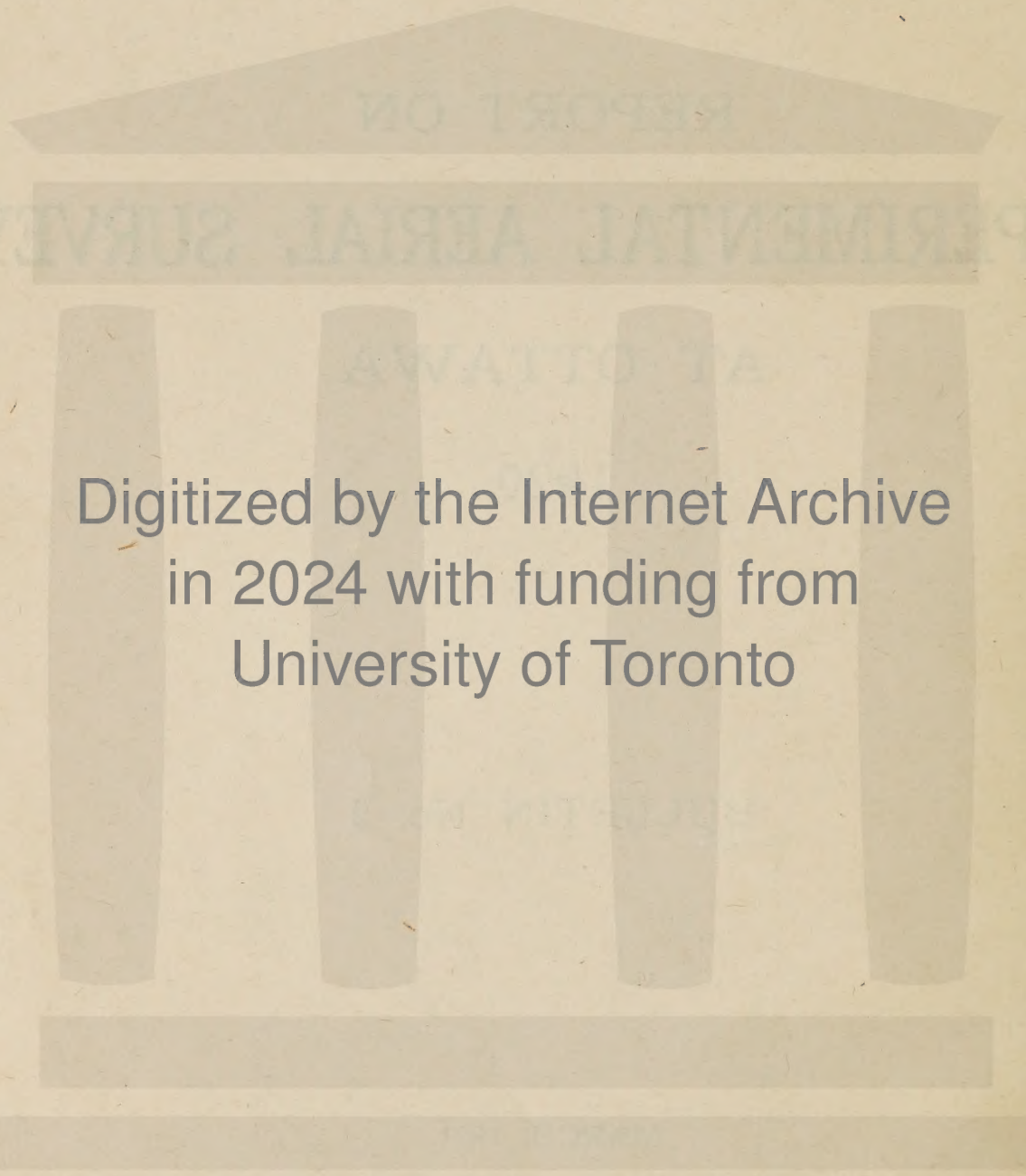
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EXPERIMENTAL AERIAL SURVEY

AT

OTTAWA, 1920

I. ENGINEER'S REPORT

A study of the remarkable developments in aerial photography during the war has aroused the conviction in the minds of many engineers and surveyors that its application to all forms of topographical survey is possible. The development of successful methods would be revolutionary in its effect and of great moment to a country such as Canada where vast tracts of unexplored and unsurveyed lands exist.

The science of photography has largely been developed in this country and it is felt that no effort should be spared to solve the problem of the application of aerial phototopography. Work was started on the problem in the fall of 1918 in conjunction with officers of the Canadian Naval Air Service and was continued by the Air Board after its formation in 1919. After much delay, due to the reorganization of the flying services subsequent to the armistice, an Air Survey Committee was formed. This, in conjunction with the Air Board, was charged with the consideration of the subject and decided that an experimental survey should be undertaken during the summer of 1920. Ottawa was chosen as a favourable site for the experiment, the terrain in the vicinity presenting favourable physical features and bodies of land and water of varying elevations in a small compass.

Equipment.

The equipment at the disposal of the Board for the purpose of this experiment was:—

Machines.—"Avro" two-seater, type 504 K, with 130 horse-power Clerget engine, and "Bristol Fighter" two-seater type with Rolls-Royce Falcon III 270 horse-power engine.

Camera.—L.B. (Mk. I) Semi-automatic Aero camera for plates 4 inches by 5 inches, manufactured by Williamson Kinematograph Co., London, England. Focal length $8\frac{1}{2}$ inches, using Ilford Panchromatic Polychrome and Wratten Panchromatic plates. This type of camera was extensively used by the Royal Air Force during the war. It is operated either by hand or wind propeller. A single lever suffices to change the plate and set the shutter. Using the mechanical changer, a single pressure on a trigger makes an exposure and at the same time sets in motion the mechanism for plate changing and resetting the shutter.

Control Survey

With no satisfactory stabilized camera mounting on the market—that is, a camera suspended so as to maintain a truly vertical optical axis which would render the photographing of the terrain on the series of plates always tangent to the earth's surface, or a device which would register the tilt of the plate—a control survey fixing accurately by triangulation many points in position and elevation, in and about the city was deemed necessary. The main points were marked with white cotton so as to be visible from the air.

The survey was to fix and control as closely as possible the relative positions of the photographs making up the mosaic and to furnish the data necessary to rectify or transform photographs badly distorted by the tilt of the plate to the horizontal plane.

Camera Installation

The installation of the camera was the first step of the operation. A fixed mounting was the only form possible under the circumstances. The "L.B." Williamson camera is provided with a "fixed" form of mounting but suspended in a cradle with bell cranks connected to springs and further guarded against vibration by a ring of sponge rubber.

The point of suspension is some distance below the plane of the centre of gravity, the point of contact between camera and mount being around a bevelled circular collar.

The plane of the centre of gravity was found by experiment to be $\frac{7}{8}$ inch below the lower surface of the aluminum casting of the camera body. Along the extreme outer ends of this camera body were bolted strips of walnut 5 feet long (across the full depth of the camera) by $1\frac{1}{2}$ inch thick and in depth such that their lower surfaces rested on the imaginary plane passing through the centre of gravity. These were made the points of support of the camera, which rested on strips of sponge rubber held in troughs. The blocks fastened to the camera were depressed an eighth of an inch into these two troughs, which prevented side play. A trial flight with the "Avro" was made with this mounting, but without success.

After this trial the use of the "Avro" was abandoned and the "Bristol Fighter" installation was brought into use with the heretofore abandoned L.B. bell-crank mounting, but the upper turret mounting was replaced by a mounting similar to that used in the "Avro" where the points of support coincided with the plane passing through the centre of gravity.

Some important changes were carried out in this mounting which contributed largely to its final success.

These are shown in sketch "A" below and comprise:—

(1) a direct contact of the bearing surfaces with only a thin sheet of rubber between instead of a sponge rubber cushion;

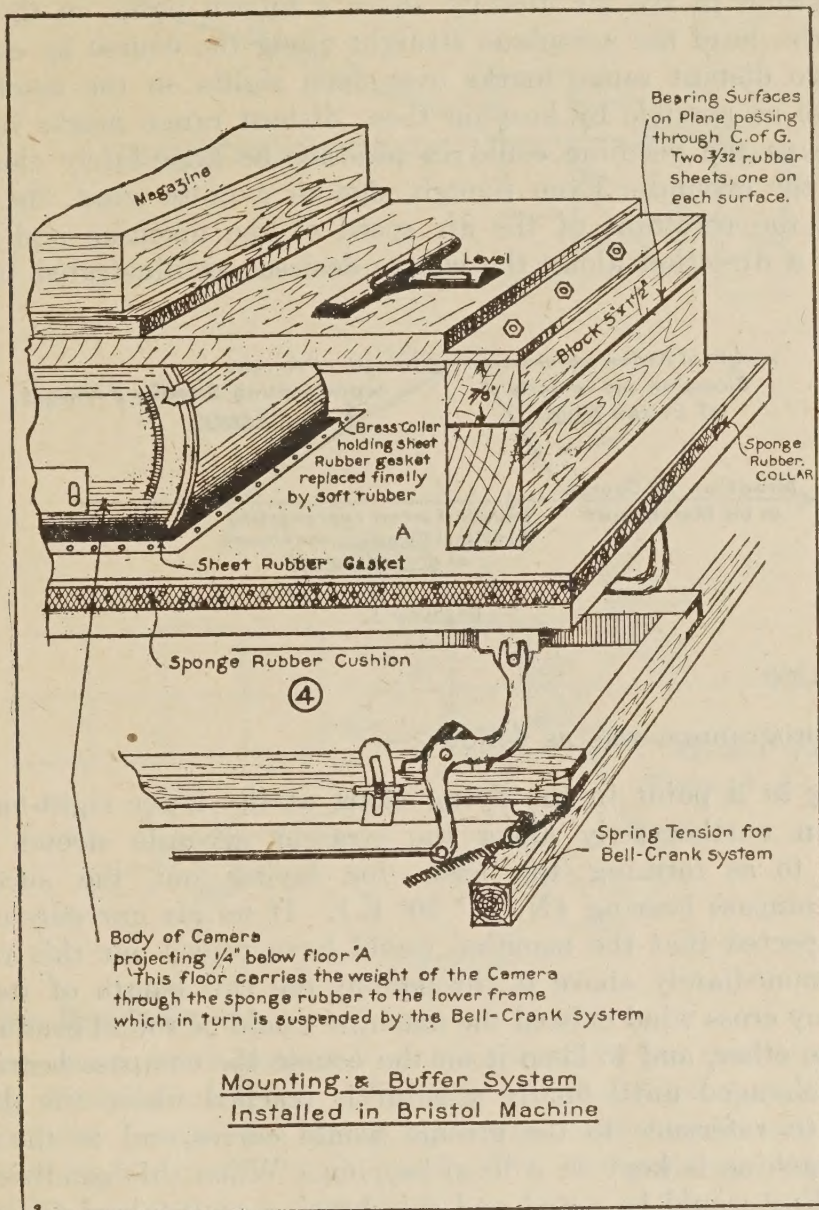
(2) the elimination of lateral contact or friction between the blocks attached to the camera and their supports by doing away with the trough which held the sponge rubber cushion, in the old mounting, and replacing it by a solid lower contact; and

(3) the introduction of a rubber collar or gasket in contact with the body of the camera itself, as shown in the sketch, to prevent the camera from sliding from its bearing surfaces.

Coming in contact with the body of the camera, which extends a quarter of an inch below the surface of the floor marked "A" in the sketch below, was a thin rubber gasket surrounding the edges of the hole and fastened to the floor. Trial runs with this mounting did not prove entirely satisfactory and some alterations were made, consisting in removing the $\frac{3}{8}$ -inch rubber ring gasket around the body of the camera and replacing it by soft rubber cubes spaced at intervals about this opening and coming into contact with the camera body, which had the same function as the gasket ring but with a greater capacity for shock absorption. In addition four wire springs were attached to each corner of the mount, giving equal pull in four directions.

With all mountings installed, provision was made by hinges at the forward side of the mounting and by wing nuts on bolts clamping to vertical slotted pieces of brass, so that the camera could be adjusted for the angle of incidence of the plane and brought into the horizontal before starting photographic operations.

Levelling transversely to the line of flight was obtained by levelling the machine on the ground and building the mounting into it so that when the camera was placed in position with the machine in normal flight the upper surface would be level.



Sketch "A."—Mounting and Buffer System Installed in "Bristol Fighter."

Flying Charts

For the guidance of the pilot two flying charts were prepared, one for a machine flying at 6,000 feet and another at 10,000 feet. These charts were used effectively for guiding the pilot in the direction of his course, the length of his trips, and their distance apart.

An almost straight piece of road was found along one of the main avenues of the city, and successive courses parallel to this stretch of road were laid out on the chart at intervals that would give 30 per cent overlap along the edges of the photographs parallel to the direction of flight.

Along each of these parallel courses were noted several specially conspicuous points on the ground easily identified from the air. In addition, range points beyond the ends of the courses were indicated which could be used in maintaining a straight course.

Distant Range Marks

The method of flying which would give the best results was considered to be as follows:—

From a position in the air directly above a known point on the ground on the course to be flown, head the aeroplane straight along the course by compass bearing; then pick up two distant range marks over open sights on the machine, and fly as straight a course as possible by keeping these distant range marks in line.

By this means the machine could in practice be kept fairly close to its course as laid out on the ground. Even though, due to a cross wind, the pilot might be “crabbing,” yet the resultant of the air speed of the machine and the wind speed would maintain a direction along the course desired, as illustrated in Figure 1.

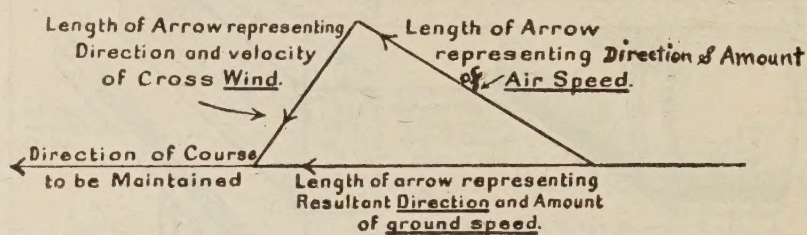


Figure 1.

Flying Programme

The flying programme was as follows:—

Commencing at a point in the flying chart at the lower right-hand corner, the machine is flown northeasterly along the straight six-mile stretch of road (previously referred to as forming the basis for laying out the successive parallel courses) on its compass bearing ($N. 72^{\circ} 30' E.$). If no air currents existed it could be reasonably expected that the machine would have traced out this road and would have remained immediately above it throughout the full length of its flight. If on the other hand any cross wind existed the machine would be found gradually moving off to one side or the other, and to keep it on the course the compass bearing would have to be gradually changed until finally a point is reached where the direction of the line of flight with reference to the ground would correspond to the desired course as long as the machine is kept on a fixed bearing. When this condition was fulfilled the compass reading would be noted and this bearing maintained for all the courses, provided no change in the direction or intensity of the wind had taken place in the meantime.

The pilot would manœuvre over this course until the desired magnetic bearing had been secured, when he could commence the photographic operations. On reaching the end of the first course, he would turn beyond the area to be photographed and again manœuvre so as to start back correctly along the adjoining course and so on until the country under consideration had been completely covered by the photographs.

Skew Photographs as Result of “Crabbing”

In all the strips of photographs taken, the skew effect due to “crabbing” was very apparent, as shown in Figure 2 below. This feature in photographic strips increases the difficulty in making mosaics and the danger of leaving blank spaces or “holes” between successive strips. To fill up these “holes” by additional photographs means an additional flight or a number of flights, and if many such holes exist the cost of filling them in approaches dangerously near the cost of the original survey.

In a mounting which allows the camera to turn freely about its optical axis, this difficulty would be eliminated as shown in the diagram (Figure 3). This would give in theory a uniform strip of photographs free from any skew effect.

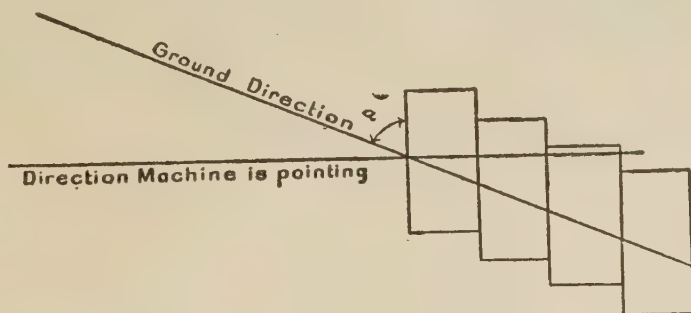


Figure 2.

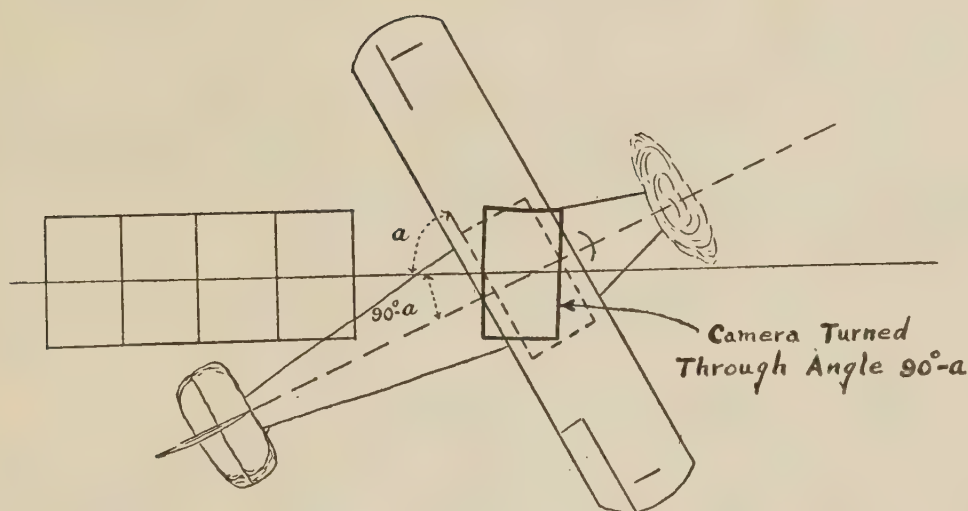


Figure 3.

Large Overlap Desirable

The flying charts were prepared on a basis of 75 per cent overlap in the photographs in the direction of flight. The cost of photographic material is small when compared with the cost of the flying operations and besides the additional cost of making further flights to fill blank spaces left, the greatest economy would appear to be secured by giving ample overlap.

MOSAICS

Small Mosaics Assembled with Prints Unrectified

A small trial mosaic was made up from some of the first photographs taken at 5,000 feet. Without any attempt at rectifying them, each was enlarged to a scale of 400 feet to one inch, based on measured lengths on the ground between points easily identified on the photograph. These enlargements were based upon measured lengths along sidewalks taken from the city engineer's office, and in the two taken over Eastview the measurements were made on the ground. From these known lengths the plates had to be enlarged by the following amounts to bring them all to the same scale, based on the measured distances in them, which are of course subject to the distortion due to the inclination of the plate and differences of elevation of the ends.

Plate No. 1	—enlarged	1.508	times
Plate No. 2	“	1.619	“
Plate No. 3	“	1.502	“
Plate No. 4	“	1.620	“
Plate No. 5	“	1.455	“

When an attempt was made to join the edges of these prints together, the scales on the edges did not coincide at all, and in order to make them coincide, the scale of No. 3 was assumed correct and numbers 2 and 4 enlarged to the scales that were found on the respective edges of No. 3 immediately adjacent. With the new scales for 2 and 4 now obtained, 1 and 5 were given a change of scale equal to that found on the edges of 2 and 4 respectively where they would join 1 and 5.

The new scales thus found were as follows:—

Plate No. 1—enlarged	1.717	times
Plate No. 2	1.619	“
Plate No. 3	1.502	“
Plate No. 4	1.425	“
Plate No. 5	1.36	“

These scales would indicate an inclined flight amounting to about 6 degrees, whereas the first series of enlargements indicated that the machine was flying in a wave motion. Neither of these suppositions can be assumed correct as measured distances on the ground shown in different parts of the same plate give different altitudes for the machine.

The conclusion of the matter is of course that all the plates were taken on planes far from parallel to the general surface of the ground over which the aeroplane was flying, and the scaled lengths on the plates of the corresponding distances measured on the ground were subject to distortion due to relief.

This final MOSAIC A fits well at the edges and makes a very good-looking photograph, but is very seriously in error as to scale. Its shortcomings are well shown up by comparing it with a tracing on transparent paper, taken from the best compiled maps of the city available.

The Same Mosaic with Rectified Photographs

The same five photographs were again taken and on each photograph were obtained two measured lengths running as nearly as could be obtained at right angles, and as far across the plate in both directions as was possible.

MOSAIC B.—These distances in each case were then plotted to the same scale (400 feet to an inch) and in the same relative direction and placed on the board of an improvised enlarging camera where the plane of the negative and that of the enlarging board were capable of being placed at any inclination. The images from the negative, of the ends of the corresponding plotted lengths, were by trial and error, then made to coincide on the enlarging board and a bromide enlargement taken. This proved no easy problem and several lenses with different focal lengths were tried before success was obtained.

The inclinations found in the plates were as follows:—

Inclination lengthwise (Machine Banking)	Inclination across (Machine Dipping)
No. 1...15 degrees	16 degrees
No. 2... 5 “	28 “
No. 3...12 “	1 “
No. 4...21 “	4 “
No. 5...24 “	0 “

MOSAIC C.—This mosaic is made up of three negatives taken at the 10,000-foot altitude and rectified by three control points in each picture and enlarged to 400 feet equal to one inch. The joining edges are slightly out owing to the errors existing, in most part due to the position of the control points being only scaled from the city map.

After these negatives had been rectified it was found that the city map which had been depended on for direction and position for at least one more point, was so much in error that the distortions given in the photographs composing Mosaics B and C were entirely erroneous and the tilts given to the plates to rectify them were no indication of the actual tilts of the camera.

MOSAIC D (see Plate I).—The mosaic of the Chaudiere and along the Ottawa river is an example of a mosaic corrected to an absolute control made by survey.

A complete coincidence of all the points in the rectifying camera could not be made, naturally so, as the points are all on different levels, but a fair average coincidence of all the points or the most widely separated three was obtained.

The tilts given to the negatives composing Mosaic D are:—

PHOTOGRAPHS FROM LEFT TO RIGHT

Inclination lengthwise (Machine Banking)	Inclination across (Machine Dipping)
0 degrees..	3 degrees
0 "	5 "
5 "	2 "
2 "	4 "

Improvised Rectifying Camera

Through the assistance of the Natural Resources Intelligence Branch and the kind co-operation of the Photographic Section, an improvised camera was put together and these rectified photographs obtained. Four movements had to be brought into adjustment before the rectified print was obtained; that is, the rocking of the copying board in two directions out of the vertical, and the rocking backward and forward of the copying board and of the lens along the horizontal base of the apparatus.

The plotted positions to the scale required were pinned to the copying board and the corresponding images in the negative made to coincide with its plotted position. The operation proved a lengthy affair with some of the negatives.

With the 12-inch Acuplat Series 1.F.8. stopped to F.16 the depth of focus was considered, for this experiment at least, sufficient without having the additional two adjustments of tilting the plate.

The operation in a regular rectifying camera is made much simpler, by the additional provision of a free movement of negative and copying board in their own planes and by combining the rocking of the copying board and lens in one operation.

A suggestion has been made that the rectified image of the negative could be projected on the underneath surface of a ground glass and the image controlled by the plotted points placed on transparent paper. The ground glass could then be replaced by a sheet of bromide for a photographic enlargement or the image traced through and used in this way for transferring to a map the topographical detail required.

The great value of the mosaic in itself is not yet fully appreciated. The amount of information it contains is infinite and the more it is studied the more information it is capable of revealing.

Errors in Mosaics

The distortions of a mosaic are chiefly at present due to an inclined plate. When this is corrected by means of control on the ground or by the design of a mounting and stabilizing device which will maintain the optical axis in a vertical position there still remains the error due to relief which obviously, as a whole, can never be eliminated from the mosaic.

Distortion due to relief will be corrected for, point by point, when it is made possible to obtain the elevations of points on the ground from the air photographs. The extent of distortion depends upon the angle at which the light from the objects enters the lense and the height of the relief. Points vertically below the camera have no distortion, but as the edges of the negative are reached the distortion gradually increases.

At the point "A" in Figure 4 below, along the margin of the lake there is no distortion. At "B" the amount of the distortion is indicated by "m"; at "C" the distortion is indicated by "n." It can also be seen from Figure 4 that the greater the altitude the more nearly parallel become the light rays, and the less the distortion due to relief.

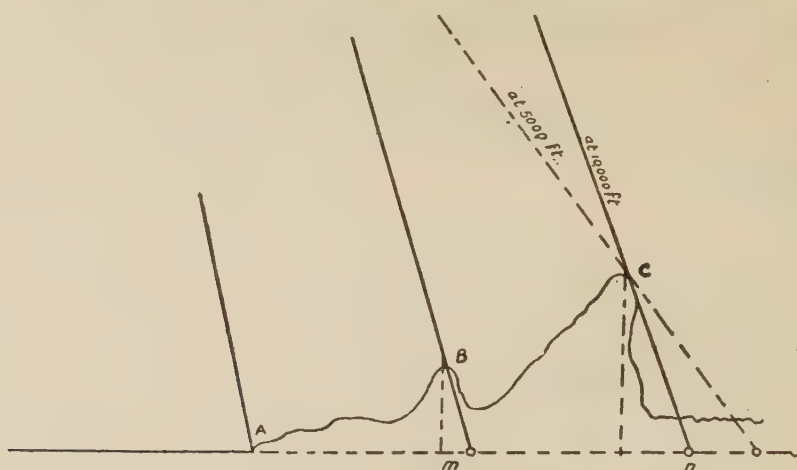


Figure 4.

Distortion due to uneven expansion and contraction of the printing paper is of the first order and must be carefully guarded against. The film, although infinitely easier to handle, especially when a large number of exposures are being made, is difficult to keep flat. Any unevenness tends to change the focus and distort the image.

Distortion Due to Inclined Plate

Over country where no control exists distortion due to the inclined surfaces of the negatives will always be present until the problem of the stabilized camera is solved.

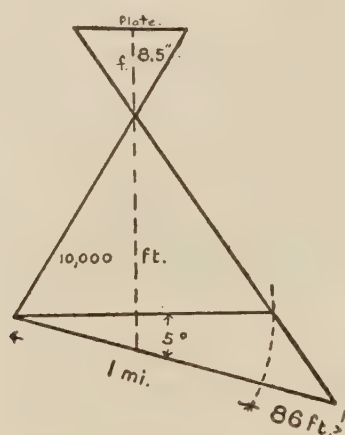


Figure 5.

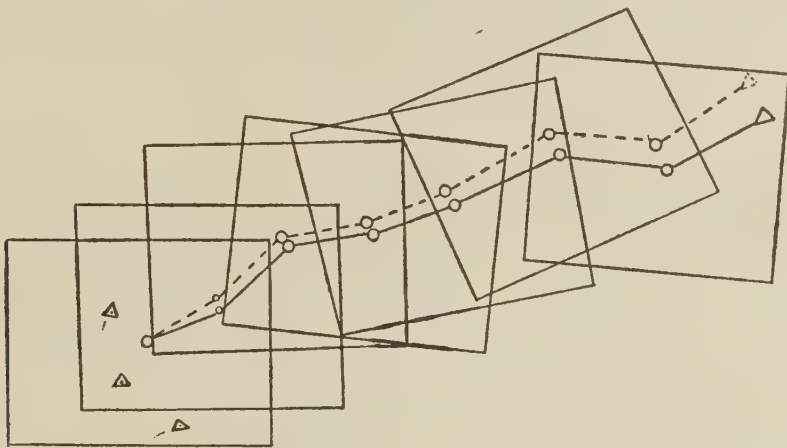
The greater the altitude the smaller becomes this distortion. At 10,000 feet with an eight and a half inch lens using a 5-inch by 4-inch plate, an inclination of five degrees would produce a total distortion (lengthwise to the plate) of 96 feet or at the rate of 86 feet for each mile of terrain covered. This is illustrated in Figure 5 above.

EXPERIMENTAL AND RESEARCH WORK NECESSARY

The information that engineers all over the world are trying to obtain is whether a large scale topographical map showing elevations by means of contours can be plotted from aerial photographs and with what degree of accuracy. This was the information desired by Mr. McArthur, International Boundary Commissioner, in asking for this experiment, and the Geodetic Survey Branch was also interested from

the same point of view. The hope had been entertained that the photographs could be rectified to a considerable degree of precision and the result of the effort to thus produce a topographical map from aerial photographs could be compared with the ground survey maps already available. The photographs so far taken, however, do not lend themselves to the investigation that was originally in mind, which was to obtain photographs with large overlap and over country where the relief was very pronounced and where the ground control was extensive and accurate.

Given sufficient overlap and well rectified photographs, a traverse of the flight of a machine can be made, by joining the successive positions of the vertical optical axis as revealed in the photographs. This can be done by simple geometrical construction, the initial requirement being that two or more control points, whose elevations are known as well, appear in the first photograph. Figure 6 below illustrates a strip of overlapping photographs adjusted between control points in accordance with this method.



Control Points .

Figure 6.

The plotted traverse of a strip of overlapping photographs could be adjusted between control points first, and later the topography worked up from the adjusted photographs. In Figure 7 below, the ground "D-F" is common to photographs "A" and "B," "E-S" is common to "B" and "C," and so on; these overlaps permit of the plotting of points in order to fix positions of each succeeding photograph.

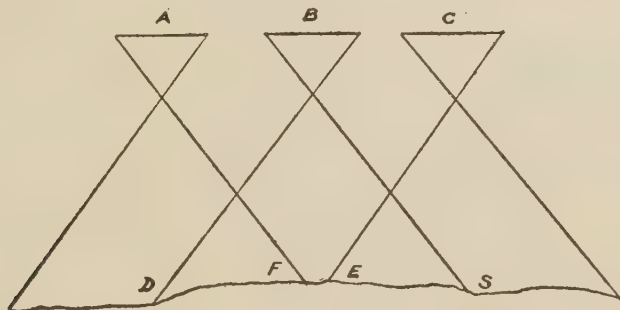


Figure 7.

The real problem to work on is not the production of complete well-balanced mosaics, purely as such, but rather the task upon which we should concentrate is the solution of the geometrical problems involved in the rectification of the photographs taken, in order that they may be capable of giving to the surveyor and engineer the correct measurements he requires and of enabling him to place accurately on the map topographical detail.

CONCLUSIONS

Present Work

It is recommended, that with the use of a rectifying camera the mosaic of the city be completed on a 400 feet to the inch scale, and when finished, work be commenced to find out just what information can be obtained from the photographic results combined with the triangulation control.

Continue Experiment

It is also recommended that the experiment commenced last summer be continued during the summer of 1921; that the field covered by the photographs now in hand be again covered with photographs, this time having a 75 per cent overlap; and in addition, it is recommended that the strip of country a quarter of a mile wide mapped by the Geodetic Survey on a scale of 1/2,000 with contour intervals of 10 feet showing all buildings, railways, roads, etc., commencing at Hull and extending up the Gatineau valley to the Thirty-one-mile Lake watershed, be covered in the same manner by photographs overlapping 75 per cent. This watershed is also mapped on a scale of 1/10,000 with a 25-foot contour interval.

Equipment

The photographic plate being less subject to warping and free from expansion is no doubt very much preferable than the film, yet the difficulty of making a large series of continuous photographs is a serious handicap, and the extra expense involved in having to return to the ground station to refill the magazines makes the film camera a much more adaptable equipment to work with. A number of aerial cameras of the self-recording type will be on the market by the spring and the question will then arise as to which will best serve the purpose.

As previously stated in the body of this report, if the question of stabilizing the camera and the rectifying of the photographs are well in hand, it would be well to direct most of the efforts of those carrying out this experiment to the consideration of developments from a geometrical standpoint. By this is meant the working out of a method of geometrically plotting points in position and elevation which are shown in two or more photographs.

Location of Camera in the Air at the Time of Exposure

It will be necessary to find out with what accuracy the actual location of the camera at the time of exposure, both as regards position and elevation, can be calculated, and the best methods of obtaining the information necessary for this calculation.

Publication of Mosaic Sheets

The production of mosaic sheets suitable for publication and distribution to the public is a large field in itself, still in its infancy, and it is hoped it will receive the attention it deserves from the branches of the service carrying out map productions.

The value of such mosaics to the general public can hardly be overestimated, as they will be far more easily read and understood than a map, and infinitely more interesting. They are invaluable to the Town Planner and go a long way in solving most of his problems. A reproduction of the complete "mosaic" map of the City of Ottawa, produced from the photographs taken last summer, is included with this report (see Plate II) and for purposes of comparison there is also appended an ordinary "Atlas" map of Ottawa drawn to approximately the same scale (see Plate III).

Fundamentally, however, from the nature of its construction, the mosaic will never take the place of the large scale city map for the use of city engineers where precise measurements are required. The ultimate problem to be solved in connec-

tion with the air photograph is to so determine its position and the inclination of the plane upon which it has been taken, that from it can be obtained the true position and elevation of points shown on it.

When this point has been reached aerial photography bids fair to revolutionize present-day methods of topographical surveying. It must not be forgotten, however, that the fundamental basis upon which aerial surveys, in common with others, are made, is a system of triangulation control which can never be dispensed with.

The whole subject is being rapidly developed and the present review of last summer's operations in the vicinity of Ottawa does not pretend to go further than merely to record the experience gained as a result of that experiment. From a technical point of view the field is now so large and is growing so rapidly that to treat the subject more exhaustively would obviously be beyond the scope of this paper.

II. JOINT REPORT OF PILOT AND AIR PHOTOGRAPHER

Suitability of Machines

The first tests were made on an "Avro" two-seater, type 504 K, with 130 horsepower Clerget engine. This machine was found unsuitable for vertical photography of this nature, owing to the insufficient ceiling of the machine, and to excessive vibration. A "Bristol Fighter," type F2B, with Rolls-Royce Falcon III engine, was then substituted for the Avro machine and gave every satisfaction. The Bristol Fighter has, with one or two exceptions, every characteristic of a good photographic machine, i.e. good visibility in all directions, sufficient performance for photographs to be taken at any altitude up to 20,000 feet; but it is a trifle sensitive on controls, and does not trim well fore and aft on the adjustable tailplane.

The difficulty experienced in flying a machine that is too sensitive on controls is that the pilot's slightest movement or relaxation after a run is started allows the machine to vary its directional, horizontal, and lateral position to a very marked degree. A machine of the DH 4 or DH 9A type is nearer to what is required for work of this special nature. These two types of machines will maintain their altitude, if the engine revolutions are not varied, by trimming the adjustable tail plane, and with only very slight corrections, to offset bumps, by the use of the control column. Directionally they are not so sensitive on the rudder, and laterally also they require a heavier touch to throw them off their normal flying position or line of flight. A machine having the characteristics of either of these two types, with a fuselage of greater dimensions in breadth and depth and of circular three-ply construction, such as the Vickers Vimy-Commercial type where no intersecting cross-bracing wires are employed, would be a great improvement as it would give sufficient room for practically any known type of camera and camera installation, without the disadvantage of obstructing the photographer in the carrying out of his duties, and would enable him to efficiently supervise his photographic apparatus.

Conclusions

From the experience gained by this test, it is obvious that a machine should be used where the pilot and photographer have a clear and unobstructed view of the intended line of flight and of the area to be photographed.

Communication between the pilot and photographer is absolutely essential, and in this connection inter-communication telephones would be of considerable help. If telephones are not practicable, the only means of communication is by way of a memo. pad and pencil. Direct speech of course is out of the question.

For aerial survey photography a pilot should receive special training in the art of careful manipulation of the machine, for the standard required in this particular line of work is above that required in taking ordinary obliques and verticals. The utmost skill is required to maintain elevation, keep the ground speed constant, and hold to an absolutely fixed course without variation irrespective of changing air conditions. This is especially so when photographing from an altitude under 7,000 feet, for on bright sunny days bumps are invariably met. Upon the success or failure of the pilot to maintain the high standard of efficiency required in this kind of work will depend to a very large extent the utility of the photographs that are taken.

The air photographer, too, must be absolutely familiar with photographic practice, and especially with conditions to be met in the air. He must have a thorough knowledge of his camera, and a good general knowledge of the type of machine in which he is being flown, especially as to its capabilities and peculiarities while in flight.

Team work is also essential between the pilot and photographer, and special operations of this nature should only be attempted with personnel who have flown or who are flying constantly together. The means of communication between the pilot and photographer in the air are not of the best at any time, but with personnel who have been employed together on work of this nature, a routine is gradually established that materially facilitates the successful conduct of the work.

Although it is not essential that the personnel carrying out the work in the air should be engineers, a general appreciation of the difficulties involved from the engineer's point of view and the problems which he is endeavouring to solve will always prove a valuable asset to both the pilot and photographer in carrying out their part of the programme. The engineer directing the work as a whole should likewise be familiar with the conditions and difficulties to be met with in the air, and if possible an opportunity should be afforded him to carry out some of the photographic work himself. This would lead to a close liaison between the work on the ground and that in the air, without which successful results cannot be obtained.

OTTAWA, March, 1921.



Approximate Scale: 1,600 feet to one inch

PLAN OF THE
CITY OF OTTAWA
FROM AERIAL PHOTOGRAPHS BY THE AIR BOARD

REPORT OF EXPERIMENTAL AERIAL SURVEY

PLATE II



COPYRIGHTED BY THE AIR BOARD, 1921

Approximate scale: 2,400 feet to one inch

